Small-Field Dosimetry

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Treatment Fields

Magna-Fields

200x200 cm²

Traditional Fields

40x40 cm²  4x4 cm²

Advance Therapy Fields

SRS/SRT
Gamma Knife
Cyber-Knife
Tomotherapy
IMRT

Small Field

4x4 cm²  0.3x0.3 cm²
TG-155: Small Fields and Non-Equilibrium Condition Photon Beam Dosimetry

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Springfield Hospital Reports Radiation Overdose Administered to 76 Cancer Patients
February 26, 2010

The New York Times reported on a recent report filed by CoxHealth medical facility in Springfield, Missouri where they admitted to over-radiating 76 cancer patients during treatment. The majority of the patients were being treated for brain cancer, and received about a 50% overdose of radiation therapy. A hospital employee improperly calibrated the machine used to administer the radiation.

Radiation Errors Reported in Missouri
By WALT BOGDANICH and REBECCA R. RUIZ
Published: February 24, 2010

A hospital in Missouri said Wednesday that it had overdosed 76 patients, the vast majority with brain cancer, during a five-year period because powerful new radiation equipment had been set up incorrectly even with a representative of the manufacturer watching as it was done.

The hospital, CoxHealth in Springfield, said half of all patients undergoing a particular type of treatment — stereotactic radiation therapy — were overdosed by about 50 percent after an unidentified medical physicist at the hospital miscalibrated the new equipment and routine checks over the next five years failed to catch the error.

Wrong detector used for BrainLab cone calibration

Stereotactic therapy delivers radiation in such high doses that usually only one treatment is required. It is commonly used to treat small tumors in the head, which must be firmly stabilized, allowing radiation to be delivered to a precise location.

The error was discovered in September 2009 only after a second physicist received training on the equipment, made by BrainLAB, and the hospital began questioning whether the machine had been installed correctly in 2004, in a process called commissioning.

The overdoses at CoxHealth occurred in a state where there is little or no government oversight of radiation therapy, a fact that Robert H. Bezanson, the hospital’s president and chief executive, chose to emphasize.

On Wednesday, he released a letter that he wrote to the Food and Drug Administration, saying that its recent decision to toughen oversight of diagnostic radiation did not go far enough.

“The initiative should be broadened to include regulation of medical radiation therapy as well,” he wrote. “We have also learned that the incident here at CoxHealth is, unfortunately, not an isolated occurrence. Rather, similar instances of medical overdosage have occurred at other hospitals throughout the country. Without increased regulation and oversight, these instances of medical overdosage will likely continue.”
Dosimetric Variation with Detectors

Das et al, J Radiosurgery, 3, 177-186, 2000
What is a Small Field?

- Lack of charged particle
  - Dependent on the range of secondary electrons
  - Photon energy
- Collimator setting that obstructs the source size
- Detector size is comparable to the field size
Electron Range & LCPE

- Electron range = $d_{\text{max}}$ in forward direction
- Lateral Charged Particle Equilibrium
- Electron range in lateral direction
  - Nearly energy independent
  - Nearly equal to penumbra (8-10 mm)
- Field size needed for LCPE
  - Lateral range
  - 16-20 mm
Source Size

90%, 70%, 50%, 30%, 10% iso-intensity line

Definition of Small Fields

IAEA/AAPM proposed pathway

Relative Dosimetry

\[ D_{w, Q_{msr}} = M f_{msr}^Q N D_{w, Q_o} k_{Q, Q_o} k_{f_{msr}, f_{ref}} Q_{msr}, Q \]

\[ \Omega_{f_{clin} f_{msr}} = \frac{M f_{clin}^Q}{M f_{msr}^Q} \left[ \left( D_{w, Q_{clin}} / (M f_{clin}^Q) \right) / \left( D_{w, Q_{msr}} / (M f_{msr}^Q) \right) \right] = \frac{M f_{clin}^Q}{M f_{msr}^Q} k_{f_{clin}, f_{msr}} Q_{msr}, Q_{msr} \]

\[ k_{f_{clin}, f_{msr}} = \frac{\left( D_{w, Q_{clin}} / (M f_{clin}^Q) \right) / \left( D_{w, Q_{msr}} / (M f_{msr}^Q) \right)}{(Output)_{rel}} = \frac{(Output)_{rel}}{(Reading)_{rel}} \]

\[ k_{f_{clin}, f_{msr}} = \frac{\left( S_{w, air} f_{clin} P_{fclin} \right)}{\left( S_{w, air} f_{msr} P_{msr} \right)} \]
Why So Much of Fuss?

- Reference (ref) conditions cannot be achieved for most SRS devices (cyberknife, gammaknife, tomotherapy etc)
- Machine Specific reference (msr) needs to be linked to ref
- Ratio of reading (PDD, TMR, Output etc) is not the same as ratio of dose

\[
\frac{D_1}{D_2} \neq \frac{M_1}{M_2}
\]

\[
\frac{D_1}{D_2} = \frac{M_1}{M_2} \cdot \left[ k, f_{clin}, f_{msr} \right]
\]
Field Size Limit for Accurate Dose Measurements with Available Detectors

Das et al, TG-106, Med Phys, 35, 4186, 2008
Impact of $k^f_{\text{clin}} \cdot f_{\text{msr}}^{Q_{\text{clin}} \cdot Q_{\text{msr}}}$
Correction Factors

Correction Factor depends on:

Field size
Source size (FWHM)
Detector type


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<th>Detector type</th>
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Published data on $k Q_{\text{clin}} f_{\text{Q_{msr}}} f_{\text{clin}}$
\[ k_{Q_{\text{clin}}, Q_{\text{msr}}} f_{\text{msr}, f_{\text{clin}}}, f_{\text{ref}}, f_{\text{psr}} Q_{\text{psr}} \]

Correction Factor vs Ion Chambers

Chung et al., Med Phys, 37, 2404-2413, 2010
Implementing a newly proposed Monte Carlo based small field dosimetry formalism for a comprehensive set of diode detectors

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Calculation of $k_{Q_{\text{clin}}, Q_{\text{msr}}}$ for several small detectors and for two linear accelerators using Monte Carlo simulations

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\[ k_{Q_{\text{clin}};Q_{\text{msr}}} f_{\text{clin}};f_{\text{msr}} \]

Cyber Knife

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<th>Detector</th>
<th>( M_{Q_{\text{clin}}}^{f_{\text{clin}}}/M_{Q_{\text{msr}}}^{f_{\text{msr}}} )</th>
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<td>0.929 (29)</td>
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Pantelis et al, Med Phy. 37, 2369-2379, 2010
Take Home Message

- Small field definition is dependent of the beam energy
- Stopping power ratio in small fields for most ion chambers is relatively insensitive to field size and is same as the reference field
- IAEA and AAPM working on guidelines for absolute dosimetry of small fields
- \( k_{\text{msr} \cdot \text{clin}} \) factor converts reading to dose and depends on
  - Machine type
  - Source size
  - Detector
- TG-155 will provide guidelines for relative dosimetry
Thanks
Sham et al, Med Phys, 35, 3317-3330, 2008
Dose and Penumbra with Spot Size

Scott et al, Med Phys, 36, 3132, 2009